Science of the Total Environment 542 (2016) 223–230

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessment of an action against environmental noise: Acoustic durability of a pavement surface with crumb rubber

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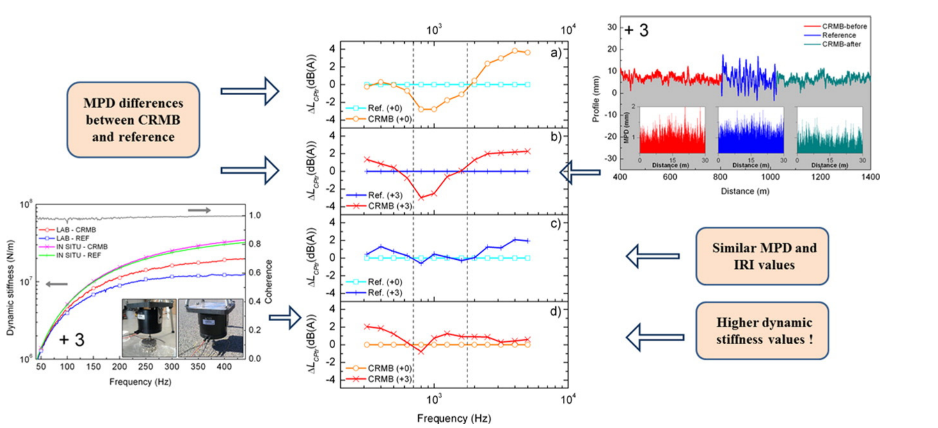
HIGHLIGHTS

- The acoustic durability of an asphalt with crumb rubber is monitored.
- Pavements with crumb rubber modified binders (CRMB) reduce rolling noise.
- CRMB asphalt pavements may be used to mitigate noise pollution in urban environments.
- Noise Action Plans (END 2002/49/EC) should include the introduction of rubber pavements.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 July 2015
Received in revised form 13 October 2015
Accepted 20 October 2015
Available online xxxx

Editor: D. Barcelo

Keywords:
Traffic noise
Crumb rubber
Noise action plans
Directive 2002/49/EC

ABSTRACT

Environmental noise is a worldwide problem that has an adverse effect in the quality of life of urban population. Some work has shown that there is a correlation between environmental noise and health issues as sleep disturbance or annoyance. This study presents the time evolution of a test track fabricated with an asphalt mixture with 20% of crumb rubber by weight of bitumen, added by the wet process. A complete surface characterization has been performed by determining tire/pavement sound levels, road texture profiles, in-situ dynamic stiffness and sound absorption of compacted and extracted sample cores. Two measurement campaigns were performed: just after mixture laying and after 3 years in service. This study confirms that the use of crumb rubber as a modifier of bituminous binders (CRMB) can improve the pavement characteristics: gap-graded mixtures with crumb rubber can be used in the action plans as urban rehabilitation measure to fight noise pollution. However, this noise reduction seems to decrease with age at a rate of approximately 0.15 dB(A) per year.

1. Introduction

Environmental noise is one of the main problems of urban agglomerations. It is well known that this noise is highly related to health issues such as sleep disturbance, annoyance or cardiovascular

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http://dx.doi.org/10.1016/j.scitotenv.2015.10.102
0048-9697/

disease (Kassomenos et al., 2014), thus, there is a growing concern in society about the risks associated with exposure to it. The 2002 Environmental Noise Directive (2002/49/EC) could be the most important action against noise worldwide. EU member states should complete their strategic noise maps (major roads, airports and agglomerations) and elaborate their relevant action plans. Many cities, inside and outside the EU have already produced their noise mapping (Suarez & Barros, 2014; Ascari et al., 2015). Noise mapping can enable authorities to implement adequate action plans to minimize the acoustic pollution. Since environmental noise, in cities, is mainly generated by road infrastructures, noise mitigation plans could be proposed in order to reduce road traffic noise in urban environments. Some of the proposed actions that have been already proposed in medium cities could be (Vogiatzis & Remy, 2014):

- Bus line management improvement.
- Implementation of bicycle paths.
- Creating temporary limited parking for vehicles.
- Introduction of new low-noise surfaces or pavement surface rehabilitation.
- Reduce vehicle speed.
- Installation of noise barriers.

This research work is focused in one of these measures against noise: Surface rehabilitation with low-noise mixtures. Noise barriers are able to solve a noise problem, but they may replace it with a visual problem or they could generate an impediment to movement through the urban spaces. However, low-noise surfaces fight noise pollution at source, where it is most effective, and it could be applied in every city landscape. The low-noise surface proposed in this research work is a gap-graded bituminous mixture with high content of crumb rubber from end-of-life tires, added by the wet process.

Crumb rubber from recycled tires is a waste material that can be used in many applications. In the road industry, the use of crumb rubber has grown over the past several years (Huang et al., 2007; Tortuma et al., 2005; Paje et al., 2010; Bueno et al., 2014; Paje et al., 2013; Vázquez et al., 2014a). Their use enhances pavement properties, and contributes to a sustainable development by achieving a reduction in the utilization of natural resources in road construction as well as to an environmental protection, since it provides a solution to the tire disposal problem (Huang et al., 2007; Adhikari et al., 2000; Myhre & Mackillop, 2002; Sienkiewicz et al., 2012). One example can be found in Spain, where a National Plan promotes the use of materials from end-of-life tire recycling with the goal of ensuring that 45% of rubber is used for bituminous mixtures by 2015 (Law, 2013).

Crumb rubber from waste tires can be incorporated in asphalt paving using two techniques: dry and wet processes. In the dry process, crumb rubber is used as a part of the aggregates in the mixture to replace some of their solid fraction. In this process, crumb rubber is not fully reacted with the bitumen. Pavements with crumb rubber offer improved resistance to rutting, reduce temperature susceptibility and improve resistance to fatigue/reflection cracking, see for example Lee et al. (2008). On the other hand, some laboratory work has shown that the use of crumb rubber could reduce the wearing course stiffness (Sandberg & Ejsmont, 2002; Trevino & Dossey, 2009); other studies, however, have concluded that rubber powder added to the binder shows an increase of the stiffness (Lee et al., 2008; Navarro & Gamez, 2010). Anywise, the stiffness of pavements with high content of CRMB may influence noise emissions from the interaction of the vehicle tires and the pavement surface. Lowering the pavement stiffness would tend to reduce tire vibration and hence tire/pavement noise generation.

The aim of the present work was to study the noise mitigation achieved and the medium term evolution of the acoustical properties of a bituminous mixture for wearing course, with high content of crumb rubber (20%) modifying the binder by the wet process. A full scale test road was rehabilitated with the experimental low-noise pavement. To study and quantify the time evolution of the experimental surface, two measurement campaigns were accomplished; just after pavement rehabilitation and after 3 years in service. The ancient replaced mixture was also measured in the first campaign with comparative purposes. Our results are used to determine if significant reductions in urban traffic noise might be achieved using pavements with high content of CRMB from waste tires, and their acoustic durability.

2. Materials and methods

The experimental test section is a 3 cm thickness wearing course based on a gap-graded mixture (BBTM 11A (EN 13108-2, 2006)), containing crumb rubber in a percentage of 20% by weight of bitumen added by the wet process (around 1.5% of the total weight of the mix). In the middle of the test section, a wearing course constructed with the same type of mixture but incorporating conventional B 50/70 penetration grade bitumen without crumb rubber was laid as a reference section. The time evolution of the two sections, subject to the same weather and traffic conditions, allows conclusions to be reached with regard to the in-service performance of the mixture with CRMB, and its acoustic durability. The ancient rehabilitated surface was an asphalt concrete type AC 16 surf S.

In order to achieve the above mentioned objective, a complete acoustical characterization after 3 years in service conditions was accomplished in the second measurement campaign: (a) acoustical monitoring utilizing two microphones located close to a test tire mounted on a special test vehicle (close proximity methodology), (b) surface profile assessment and texture evaluation by means of the Mean Profile Depth (MPD) and the International Roughness Index (IRI), (c) dynamic stiffness assessment on the test sections and on samples (laboratory), and (d) sound absorption evaluation of both compacted specimens and sample cores taken from the experimental surface with CRMB. Results from the wearing course have been compared with those obtained during the first measurement campaign, from the newly laid surface, and from the ancient mixture that was rehabilitated with the gap-graded bituminous mixture proposed (Paje et al., 2013).

2.1. Bituminous mixtures

Two gap-graded bituminous mixes with a maximum aggregate size of 11 mm were prepared with the same type of aggregates but different type of bitumen. The bitumen used in the experimental section, 8% of the total mix weight, is a high viscosity modified bitumen with crumb rubber with a maximum size of 1 mm and a regular particle morphology. For the reference section, the mix has a bitumen content of 5% of the total mix weight. The main difference between both mixtures is found in the bitumen used (Table 1). The employed bitumen's differ significantly due to the addition of rubber powder from waste tires.

Two types of sample cores were used to evaluate the evolution of the sound absorption capacity: a first set of measurements was made on compacted Marshall just after the pavement rehabilitation. Besides, a second set of samples was taken directly from the test sections at different positions, after 3 years in service conditions, and cut to uniform shape. These sample cores were also employed for dynamic stiffness measurements in laboratory.

Table 1
Binder's specifications.

	Binder	
	CRMB	B 50/70 (reference)
Penetration (0.1 mm, 25 °C) EN-1426	19	57
Ring and ball softening point (°C) EN-1427	80	51